PROGRESS REPORT OF COMMITTEE ON MECHANICAL ANALYSIS OF SANDS

The Committee on Mechanical Analysis of Sand has up to this time delayed the preparation of a report principally because of the fact that it is thought to be one of the principal duties of this committee to submit a proposed standard method of conducting such analyses and because during the past two years, especially, the United States Bureau of Standards at Washington, D. C., has been active in securing coöperation and joint action of parties interested in the selection and adoption of standard screens. It is recognized that standard screens are required not only for the mechanical analyses of sands but also in many other industries, yet it is believed that it is to the best interests of all having to do with such sand analyses that the one standard be used for all. There are obvious advantages in having the one standard screen scale available for all purposes and there is no apparent advantage in having a separate or distinct set of standard screens for testing sand.

Early action of the Bureau of Standards in the matter of standardizing sieves resulted in the adoption of certain specifications standardizing 200 and 100-mesh sieves used primarily for testing cement. Subsequently, early in 1917, responding to the demands of industry, the Bureau of Standards called a conference at Washington including representatives of practically all national engineering and technical organizations and others interested in the adoption of standard sieves. The conference, after considering various screen scales, adopted a standard screen scale and recommended that it be adopted generally by scientific, technical, and engineering societies and committees as part of their specifications for materials and methods of tests; also that it be used by private firms who have need of standard sieves. The committee recommends the adoption of the standard screen scale for sieves used in the mechanical analysis of sands.

The screen scale is essentially metric. The sieve having an opening of 1.0 mm. is the basic one and the sieves above and below this in the series are related to it by using in general the square root

of 2, or 1.4142, or the fourth root of 2, or 1.1892, as the ratio of the width of one opening to the next smaller opening. The first ratio, that is, 1.4142, is used for openings between 1.0 mm. and 8.0 mm., while the second ratio is used for openings below 1.0 mm. to give more sieves as required in that part of the scale.

Because of the possible wide range of openings in sieves now manufactured with a given number of meshes of wire per unit length, due to the use of wires of different diameters, and because of the consequent confusion and uncertainty which arise in designating sieves by the number of meshes per unit length, the sieves of this series are designated by the width of the opening in millimeters, as for example a 1.41 mm. sieve, or a 0.36 mm. sieve. The committee recommends that this method of designating sieves be adopted instead of the customary method of designating the number of meshes per inch.

To meet the need for sieves of this series at the present time the committee has included a temporary provision in the specifications for the acceptance of sieves of slightly different mesh and wire diameter than that called for in the screen scale, provided the resultant opening is the same as the nominal opening within a small range. This will make possible the use of a number of sieves now on the market in which the ratios of wire diameter to opening are only slightly different from those of the screen scale.

Specifications for standard sieves

Sieves shall be of brass constructed in diameters of 20 cm. (7.87 inches) or 15 cm. (5.91 inches). These are the outside diameters of the bottom of the sieves or the inside diameters of the top of the sieves.

Wire cloth for standard sieves shall be woven (not twilled, except that the cloth of 0.062-mm. sieves, may be twilled until further notice) from brass, bronze, or other suitable wire and mounted on the frames without distortion. To prevent the material being sieved from catching in the joint between the cloth and the frame, the joint shall be smoothly filled with solder, or so made that the material will not catch.

The number of wires per centimeter of the cloth of any given sieve shall be that shown in the accompanying table 1, in the second column, headed "Mesh," and the number of wires in any whole centimeter shall not differ from this amount by more than the tolerance given in the 5th column, that headed "Mesh" under the heading "Tolerances." No opening between adjacent parallel wires shall be greater than the nominal width of opening for that sieve by more than the following amounts:

Five per cent of the nominal width of opening for the 8-mm. to 1-mm. sieve inclusive.

TABLE 1

Standard screens for mechanical analyses of sand

	WIDTH OF OPENINGS	MESH	WIRE DIAMETER	RATIO WIRE DIAMETER TO OPENING	TOLERANCES	
					Mesh	Diameter
Metric	8.00	1.00	2.00	0.25	0.01	0.008
Customary	0.315	2.54	0.079	0.25	0.03	0.003
Manufactured	8.05	2.5	0.083	0.26		
Metric	5.66	1.4	1.48	0.26	0.01	0.08
Customary	0.223	3.56	0.056	0.26	0.03	0.003
Manufactured	5.66	3.5	0.063	0.28		
Metric	4.00	2.0	1.00	0.25	0.02	0.05
Customary	0.157	5.1	0.039	0.25	0.05	0.002
Manufactured	4.04	5.0	0.041	0.26		
Metric	2.83	2.75	0.81	0.29	0.02	0.05
Customary	0.111	7.0	0.032	0.29	0.05	0.002
Manufactured	2.82	7.0	0.032	0.29		
Metric	2.00	3.9	0.56	0.28	0.04	0.05
Customary	0.079	9.9	0.022	0.28	0.1	0.002
Manufactured	2.03	10.0	0.020	0.25		
Metric	1.41	5.0	0.59	0.42	0.08	0.025
Customary	0.0555	12.7	0.0232	0.42	0.2	0.001
Manufactured	1.42	12.0	0.027	0.69		
Metric	1.00	7.0	0.43	0.43	0.15	0.020
Customary	0.394	17.8	0.0169	0.43	0.4	0.0008
Manufactured	1.01	18.0	0.016	0.41		
Metric	0.71	9.0	0.40	0.56	0.3	0.012
Customary	0.0280	22.9	0.0157	0.56	0.75	0.0005
Manufactured	0.72	22.0	0.017	0.60		
Metric	0.50	12.0	0.33	0.66	0.4	0.012
Customary	0.0197	30.5	0.0130	0.66	1.0	0.0005
Manufactured	0.50	3.0	0.0135	0.68		
Metric	0.36	16.0	0.26	0.72	0.6	0.010
Customary	0.0142	40.6	0.0102	0.72	1.5	0.0004
Manufactured	0.36	40.0	0.011	0.79		

TABLE 1—*Concluded*

	WIDTH OF OPENINGS	MESH	WIRE DIAMETER	RATIO WIRE DIAMETER TO OPENING	TOLERANCES	
					Mesh	Diameter
Metric	0.25	23.0	0.185	0.74	1	0.008
Customary	0.0098	58.4	0.0073	0.74	3	0.0003
Manufactured	0.25	60.0	0.007	0.72		
Metric	0.17	31.0	0.15	0.88	1	0.008
Customary	0.0067	78.7	0.0059	0.88	3	0.0003
Manufactured	0.17	80.0	0.00575	0.85		
Metric	0.125	47.0	0.089	0.71	1.5	0.008
Customery	0.0049	119.4	0.0035	0.71	4	0.0003
Manufactured	0.119	120.0	0.0036	0.77		
Metric	0.088	67.0	0.061	0.69	2.5	0.005
Customary	0.0035	170.2	0.0024	0.69	6	0.0002
Manufactured	0.089	170.0	0.0024	0.69		
Metric	0.062	98.0	0.040	0.65	3.5	0.005
Customary	0.0024	248.9	0.0016	0.65	9	0.0002
Manufactured	0.061	250.0	0.0016	0.67		

Ten per cent of the nominal width of opening for the 0.71-mm. to the 0.36-mm. sieve, inclusive.

Twenty per cent of the nominal width of opening for the 0.25-mm. to the 0.125-mm. sieve, inclusive.

Thirty per cent of the nominal width of opening for the 0.088-mm. and the 0.62-mm. sieve, inclusive.

The diameters of the wires of the cloth of any given sieve shall be that shown in the third column of table 1 headed "Wire Diameter," and the average diameter of the wires in either direction shall not differ from the specified diameter by more than the tolerance given in the last column of table 1, that under "Tolerances" headed "Diameter."

Sieves shall be rejected for obvious imperfections in the sieve cloth or its mounting, as for example, punctured, loose or wavy cloth, imperfections in soldering, etc.

Until further notice, to permit the use of sieves now on the market which have slightly different mesh and wire diameters from that specified above, sieves will be satisfactory if the measurements of mesh and wire diameters show the resulting average width of opening to be within 4 per cent of the nominal opening of a given sieve, and the ratio of wire diameter to opening of the sieve in question is within 0.03 of that given in table 1, in the column headed "Ratio Wire Diameter to Opening" for the 8-mm. to the 2-mm. sieves, inclusive, and within 0.06 of the ratio given for sieves of smaller openings than 2 mm.

The Bureau of Standards has announced that it will test sieves of the standard screen scale to determine whether they conform to the specifications which follow. This test will consist of an examination of the mesh of both the warp and shoot wires of the cloth to ascertain whether it comes within the tolerances allowed; also measurements of the diameter of wires in each direction to determine the average diameter; also a measurement of any large openings to determine whether they exceed the limits given in these specifications; also, an examination of the sieves to discover any imperfection of the sieve which may seriously affect its sieving value. Sieves which pass the specifications will be stamped with the seal of the Bureau and will be given an identification number and a certificate will be furnished for each sieve that passes the requirements.

For sieves which fail to meet the specifications reports will be rendered showing wherein the sieve was not up to the standard.

In the accompanying Table 1 the committee has shown the specifications for standard screens which it recommends for adoption by the Society. The first 7 sieves listed, that is from the 8-mm. to the 1.0-mm. sieve, include the first 7 sieves of the entire screen scale. For the sieves smaller than the 1.0 mm. sieve, only the alternate sieves of the screen scale are included.

In the table are shown the meshes per inch and diameters of wire, together with their tolerances, all expressed in millimeters and inches. Widths of openings are expressed also in millimeters and inches. There is also shown for each standard screen specifications for that sieve now manufactured which most nearly approaches the suggested standard screen, as regards width of opening and ratio of wire diameter to opening.

The committee wishes to call attention to the importance of the latter factor or ratio. Referring to the table, it will be observed that the ratio of wire diameter to opening varies from 0.25 to 0.88, generally increasing with the finer cloth. In practice it is found that the diameter of wire used should be as small as will withstand the service required, because material will not pass cloth composed of coarse wire so freely as it will pass cloth woven of fine wire. This fact undoubtedly is the principal reason why confusion has arisen in the past when it has been attempted to establish a relation between the diameter of opening and the size of the particle passing the opening, that is the separation of the sieve. For instance, in

the case of two sieves having the same width of opening, that in which the wire has the larger diameter will pass the larger particle, and vice versa.

Another feature of the manufacture of wire cloth which has considerable importance in affecting the separation of a screen is the weave. The finer screens are frequently made of twilled cloth, that is each wire crosses above and below each adjacent two wires, while in the plain woven cloth, each wire crosses above and below each adjacent wire. The plain woven cloth is always used for the coarser sieves. Experience shows that larger particles will pass through twilled cloth than through plain woven cloth of the same width of opening.

The committee recommends that the cloth in all of the standard sieves be plain woven and not twilled, although for the present it may be necessary to use twilled cloth for the 0.062 mm. sieve.

Methods of making mechanical analysis. A mechanical analysis of sand is generally accomplished in the following manner: The selected sieves are nested with the coarsest at the top varying to the finest at the bottom. For the 8 inch diameter sieves 300 grams and for the 6-inch sieves 100 grams of the sand to be analyzed are dried and placed in the top sieve, the nest of sieves is shaken in a mechanical shaker practically to refusal of any further separation, the sieves separated, and beginning with the finest sieve the sand remaining on each sieve is weighed accumulatively. The results are then plotted to a suitable scale.

There are six factors which control the results of a mechanical analysis, as follows: the selection of a representative sample; the quantity of material taken for analysis; the number and rapidity of the shakes; the accuracy of the weights of the separated portions; the rating of the sieves to determine their separations; and finally, the interpretation of results. Each of the above features has an important bearing on the accuracy and reliability of a mechanical analysis and should be given proper consideration.

The material to be analyzed should preferably be in its natural moist condition when sampled as otherwise it tends to separate. When dry it should be handled with a scoop and thoroughly mixed. In sampling a pile of moist sand a large sample should first be taken of several portions from different parts of the material, these portions mixed, the resultant sample quartered and the process continued until finally there is secured a sample of the required size.

The amount of sand used should be as large as practicable. For the 8-inch sieves 300 grams of graded sand and for the 6-inch sieves 100 grams may well be used. More than these quantities tend to stretch and clog the cloth and are not readily separated by shaking.

A mechanical shaker is required, especially where a large number of analyses are to be made. Several satisfactory machines are on the market. The essential feature of such a machine is that its speed shall be properly controlled. Experience will readily indicate the period of shaking required in the machine which should be operated by trial, using the required amount of sand until there is practically no further passage of sand grains through the screens.

In the case where a mechanical shaker is not available, as in field work, hand shaking when carefully executed will give results commensurate with a mechanical shaker. Experience indicates that when using the portions of sand indicated above, hand shaking for about 200 double horizontal shakes will give a satisfactory separation.

The accuracy of the weighing depends upon the precision of the balance used. Weights should be taken to 0.1 gram, with the understanding that the weights may be slightly in error when the total weight is greater than 100 grams.

The interpretation of a mechanical analysis depends primarily upon two features, the size of separation as determined for each sieve and the method of plotting and recording results.

At least two methods are available to determine directly the separation of a sieve, either to measure the three principal diameters of representative sand grains and to compute their average diameter or to count and weigh the grains and to compute the volume of the average particle obtained by dividing the weight of the average grain by its specific gravity. There is thus obtained the mean volume of the average grain which is considered to be a sphere and its diameter computed and taken as the separation of the sieve. The former procedure is recommended as giving the best results for large gravel; also for the extremely small grains of sand such as will pass a sieve of 200 meshes to the inch. A pair of calipers may be used to measure the diameters of the larger particles and a microscope to measure the smaller particles. The second procedure is the one commonly used for sieves ranging from 4 to 140 meshes per inch and requires the accurate separation of the sample, the counting and weighing of the grains and the determination of the specific

gravity of the grains. It will be observed that the rating of a nest of sieves in this manner is at best a tedious and difficult procedure.

Whatever the method used in determining the sizes of the grains the securing of an accurate sample is of first importance. The procedure is as follows: a sample of sand is put through the sieve in exactly the same manner as in making a mechanical analysis. Each sieve is then shaken a little by hand and the last particles going through are shaken over the next finer sieve. The last material remaining on the next finer sieve is considered the separation of the sieve.

Experience indicates that the results of the determinations of the sizes of separation are dependent almost entirely upon the selection of proper samples, because two determinations of the separation of a sieve using portions of the same sample should give the same results to the required accuracy when reasonable care is used. Owing to characteristic variation in the sizes and shapes of the grains it is desirable to use several kinds of sand from different locations or sources in order to determine the average separation. Where sieves are required largely for the mechanical analysis of a particular sand the procedure may properly be limited to determinations of the sizes of separation with this material only.

A comparative method of rating sieves also suggests itself in the event that there is available a nest of sieves already rated. A representative sample of sand may then be analyzed in the usual manner by the rated sieves and again may be separated into weighed portions by the unknown sieves. By plotting the percentages of the total weight on the curve of the analysis as determined by the first set sieves, the separations of the unknown sieves may be read directly. The comparative method has obvious advantages and in general is one of the methods now used by the Bureau of Standards to test 100 and 200 mesh cement sieves.

Because the method of rating a nest of sieves by counting and weighing the grains is a very tedious and expensive procedure, investigations have been made from time to time to determine whether or not there is any definite relation or relations between the width of opening of a screen and the size of separation. In view of the fact that in the past screens have been made with little if any attention to definite specifications or tolerances of mesh and diameters of wire it is not surprising that these investigations were not satisfactory and did not indicate whether or not such a relation exists.

Part of the difficulty undoubtedly was attributable to the personal factor and also to the use of grains of sand of different degrees of sharpness.

In table 2 are shown the openings of the standard screens and the probable sizes of separation that may be obtained with sieves built under the accompanying specifications, especially in regard to tolerances of mesh and diameter of wire. Experience indicates that

TABLE 2

Relation between sizes of opening and sizes of separation of sieves

SIEVE OPENING	MESH	RATIO WIRE DIAMETER TO OPENING	RATIO SIZE OF SEPARATION TO OPENING	CORRESPONDING SIZE OF SEPARATION
mm.	*inches*			*mm.*
8.00	2.54	0.25	1.09	8.72
5.66	3.56	0.26	1.09	6.17
4.00	5.1	0.25	1.09	4.36
2.83	7.0	0.29	1.09	3.08
2.00	9.9	0.28	1.09	2.18
1.41	12.7	0.42	1.10	1.55
1.00	17.8	0.43	1.10	1.10
0.71	22.9	0.56	1.10	0.78
0.50	30.5	0.66	1.10	0.55
0.36	40.6	0.72	1.11	0.40
0.25	58.4	0.74	1.11	0.28
0.17	78.7	0.88	1.11	0.19
0.125	119.4	0.71	1.11	0.14
0.088	170.2	0.69	1.11	0.10
0.062	248.9	0.65	1.20*	0.07

* Ratio assumed for twilled cloth. For plain woven cloth ratio is 1.11 and separation is 0.068 mm.

many sieves used for the mechanical analyses of sand would not come within these specifications especially because the spacing of the wires in one direction is not correct and within these specifications. Moreover it is not uncommon to find the wires used in the cloth to be of larger diameter and unsatisfactory on this account.

The Committee is not in accord as to the value of factors to be applied to determine the separation of a sieve with relation to its average width of opening. It is obvious, however, that the use of the accompanying specifications should result in a material improvement in the manufacture of testing screens; also that the use of such factors would be of great assistance in many cases in determining

the relation between analyses made by different investigators and expressed by either one of the two standards of measurement. Moreover, it is apparent that the use of the standard screens in specifications of material required has obvious advantages as compared with the use of such terms as will define the sizes of the particles, or of selected arbitrary percentages by weight of the particles.

Furthermore, the Committee is not in accord as to the standard of measurement which can best be adopted for rating sieves required for the mechanical analysis of sand. It is of course true that the principal use of such analyses, so far as this Association is concerned, is for the determination of the characteristics of sand required or used for filtration purposes. Moreover, up to the present time, the standard of measurement has been the size of separation of a sieve and not the width of opening. The screen scale now recommended by the Bureau of Standards for adoption is based upon the width of opening and not upon the size of separation. The committee is not yet prepared to report upon the adoption or uses of either standard of measurement because further investigation is required to reach a conclusion in this matter.

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